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## The Factors of Technology, Organization and Environment Influencing the Adoption and Usage of Big Data in Korean Firms

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# **The Factors of Technology, Organization and Environment Influencing the Adoption and Usage of Big Data in Korean Firms**

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## **ABSTRACT**

Big data is expected to be the innovation engine driving new digital transformations of businesses. The proportion of firms implementing and utilizing big data, however, is not high. There exist many challenges for promoting the business diffusion of big data. The purpose of this paper is to identify and prioritize the factors influencing the big data adoption and usage in firms from technology-organization-environment (TOE) perspectives. The results of analytic hierarchy process (AHP) method using the data collected from the expert survey in Korea are follows: The perception of benefits from big data and technological capability are identified as the critical determinants of the big data adoption. The compatibility with existing system, data quality and integration, and security and privacy are ranked highly in technology context. Management support and financial investment competence for the implementation and utilization of big data, and the government support and policy are identified as the adoption and usage factors from organization and environment aspects, respectively. We proposed the suggestions for activating big data in firm from the findings.

**Keywords:** Big Data, Adoption, Usage, Innovation Diffusion, Technology-Organization-Environment Model, Digital Transformation, AHP

## **1. Introduction**

The explosive growth of data driven by information and communication technologies such as social media, mobile contents and business informatics has opened up a new digital transformation in society, government and business through the big data since the early 2010s (Accenture, 2014). Big data is likely to be an innovative IT paradigm beyond a phenomenon or a fashion with the advance of Internet of Things (IoT), cloud computing and 3D multimedia. Many research institutes and consulting firms expects that big data would contribute to the

national economy as well as the private sectors through efficient operations, cost reduction and new market development (McKinsey Global Institute, 2011; Gartner, 2014). Big data is especially reported to offer both new opportunities and enormous threats in business perspective since the firms' use of data may help securing competitive advantage and high performances (LaValle et al., 2013).

It is expected that big data would play the role as the strategic necessity in firms, but the width and depth of the diffusion do not meet the expectations. According to the survey report of National Information Agency (NIA, 2014), the proportion of big data adoption was less than 10% in Korean firms as of 2014. The other survey results indicate that there are many challenges for the big data diffusion of firms, including system, management, data, internal capabilities and external factors (IBM, 2012; Accenture, 2014; Gartner, 2014).

The purpose of this study is to identify and prioritize the factors influencing the adoption and usage of big data in firms using Technology-Organization-Environment (TOE) framework. To the end, we shall investigate the factors suitable for big data adoption and usage, after reviewing the existing survey reports on big data and the prior studies on IT adoption applying TOE framework. We also shall prioritize the factors according to their importance and relevance using the analytic hierarchy process (AHP) method.

## **2. Research Backgrounds and Model**

### *2.1 The outlook of big data*

With the advance of information and communication technologies, the amounts of data generated by digital media and devices have increased exponentially since 2000 (Gartner, 2014). The evolution of Internet and mobile communication has changed the ways of life and production, and new IT innovations including social media, VoIP and enterprise informatics have rapidly diffused. Therefore, the data created every day were very huge as to 2.5 exabytes ( $2.5 \times 10^{18}$ ) as of 2012 (IBM, 2013). The clouding computing, Internet of Thing and 3D multimedia are predicted to accelerate the explosive increases of data. The growth of data having attributes such as volume in data amount, velocity in data transmission speed, and variety in data sources has driven the new digital transformation called big data (META Group, 2001; IBM, 2012).

The advent of big data is related with social needs, data technology development as well as data growth. Because big data could be used for responding to climate change, disease prevention, and others through data science, it is expected to be a multipurpose social capital. The data related technology including data storage,

data processing and data analyzing has evolved significantly in terms of technology capability and cost, which has greatly expanded the market and technological potential of big data (National IT Industry Promotion Agency, 2015).

Big data is composed of data infrastructure and data application (IBM, 2012). Data infrastructure includes the technology related with collection, storage and analyzing of data, and data application refers to the various application in industry and public sectors utilizing data infrastructure. Big data is especially expected to be a strategic necessity for creating new market opportunities and competitive advantages to businesses through data application (McKinsey Global Institute, 2011). Big data would help the firms in cost reduction, efficient operations, product development and innovation, customer segmentation, and customer retention across the value chain.

The survey of 318 firms worldwide conducted by Tech Pro Research (2015) revealed that firms undergoing a big data project were 30 percent of the total as of 2015. Whereas the survey of 13,186 companies conducted by National Information Agency (NIA, 2014), less than 10% in Korean firms have adopted big data as of 2014. According to IDC (2012), the big data market worldwide was estimated to grow faster by 39.4% annually to reach \$16.9 billion in 2015 from \$3.2 billion in 2011. In sum, these reports show the proportion of firms adopting big data is not high because big data is still in early stage of development, but it has the likelihood of the rapid diffusion in specific sectors including IT, logistics, telecommunications and e-commerce.

## *2.2 The surveys on big data and the prior studies using TOE approach*

Global consulting firms and research institutes have conducted the surveys on the adoption and usage of big data in enterprises as shown in Table 1. IBM (2012) conducted the survey of 1,144 professionals from 95 countries on big data. The report presents that the obstacles of big data adoption would be the lack in success cases, management support, data quality and technology competence. According to the survey of 1,000 companies that have implemented big data by Accenture (2014), there are many challenges for big data adoption and usage, including security, budget, operating capability and system integration. The expert survey of 302 consultants worldwide by Gartner (2014) shows technology value and capability, data integration, funding and organization issues are challenges for big data adoption. National Information Agency (NIA, 2014) carried out the survey of 13,186 companies in Korea, and the result presented the lack of economic and technical capabilities were presented as the main causes of the low diffusion.

In sum, these results reveal that the critical factors influencing the adoption and usage of big data are the benefits perception, data concerns including data integration and data quality, security and privacy, financial costs, technology capabilities, management and organization support, and strategy from technological and organizational viewpoints. These factors are mainly concentrated on data concerns, technological and organizational issues, and internal readiness relevant to big data.

**Table 1.** The Survey Results on Big Data Adoption

Institute	Respondents	Finding	Institute	Respondents	Finding
IBM, 2012	1,144 professionals from 95 countries	<ul style="list-style-type: none"> <li>▪ Obstacles of big data adoption <ul style="list-style-type: none"> <li>- Lack of successful cases</li> <li>- Lack of management support</li> <li>- Low data quality</li> <li>- Lack of technical and analytical skills</li> </ul> </li> </ul>	Accenture, 2014	1,000 companies that have implemented big data in 19 countries	<ul style="list-style-type: none"> <li>▪ Challenges for big data adoption and usage <ul style="list-style-type: none"> <li>- Security</li> <li>- Budget</li> <li>- Capabilities to implement and operate</li> <li>- Integration with existing systems</li> </ul> </li> </ul>
Gartner, 2014	302 consultants worldwide	<ul style="list-style-type: none"> <li>▪ Challenges for big data adoption <ul style="list-style-type: none"> <li>- Understanding the value</li> <li>- Risk and governance issues</li> <li>- Skill and capabilities</li> <li>- Data integration and infrastructure</li> <li>- Big data strategy</li> <li>- Funding</li> <li>- Leadership and organizational issues</li> </ul> </li> </ul>	NIA, 2014	13,186 companies in Korea	<ul style="list-style-type: none"> <li>▪ Obstacles to big data adoption <ul style="list-style-type: none"> <li>- Burden of economic costs</li> <li>- Lack of internal capabilities for big data</li> <li>- Security and privacy risk</li> <li>- Technological complexity</li> <li>- Poor performance of big data system</li> </ul> </li> </ul>

Table 2 shows the prior studies on the determinants of IT adoption and usage using Technology-Organization-Environment (TOE) framework. The factors derived from empirical analysis were benefit or relative advantage, complexity or simplicity, compatibility, and security or privacy in technological context. Management support, technology competence, and financial costs or budget were the critical factors in organizational context. Competitor pressure and government policy or regulatory supports were related with the IT adoption in environmental context.

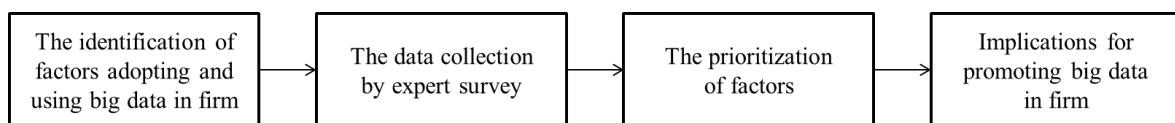
**Table 2.** Prior studies on IT adoption from TOE framework

Category	Factors	Related TOE studies
Technology	Benefit/ relative advantage	Iacovou et al. (1995); Thong (1999); Kuan and Chau (2001); Gibbs and Kraemer (2004); Lin and Lin (2008); Low et al. (2011); Cao et al. (2014); Hsu et al. (2014); Lin (2014); Oliveira et al. (2014); Gangwar et al. (2015); Yang et al. (2015)
	Complexity/ simplicity	Thong (1999); Wang et al. (2010); Lian et al. (2014); Oliveira et al. (2014); Gangwar et al. (2015); Yang et al. (2015)
	Compatibility	Thong (1999); Wang et al. (2010); Cao et al. (2014); Oliveira et al. (2014); Gangwar et al. (2015); Yang et al. (2015)
	Security and privacy	Cao et al. (2014); Lian et al. (2014)
Organization	Management support	Low et al. (2011); Cao et al. (2014); Lian et al. (2014); Lin (2014); Oliveira et al. (2014); Gangwar et al. (2015); Yang et al. (2015)
	Technology competence	Kuan and Chau (2001); Zhu et al. (2003); Xu et al. (2004); Lian et al. (2014)
	Financial costs/ budget	Kuan and Chau (2001); Gibbs and Kraemer (2004); Cao et al. (2014); Lian et al. (2014); Lin (2014); Oliveira et al. (2014)
Environment	Competitor pressure	Zhu et al. (2003); Lin and Lin (2008); Wang et al. (2010); Low et al. (2011); Cao et al. (2014); Lin (2014); Gangwar et al. (2015); Yang et al. (2015)
	Partner pressure	Zhu et al. (2003); Wang et al. (2010); Low et al. (2011); Cao et al. (2014); Gangwar et al. (2015); Yang et al. (2015)
	Government policy/ regulatory supports	Kuan and Chau (2001); Gibbs and Kraemer (2004); Xu et al. (2004)

\* TOE: Technology-Organization-Environment

### 3. Research Model and Methodology

The purpose of this study is to investigate the factors influencing the adoption and usage of big data in firms. This study begins with identifying factors identification of big data adoption in firms, and then prioritizes the factors according to the impact and relevance through AHP method as shown in Fig. 1. We propose the suggestions for promoting of big data adoption in firms from the findings of this study.

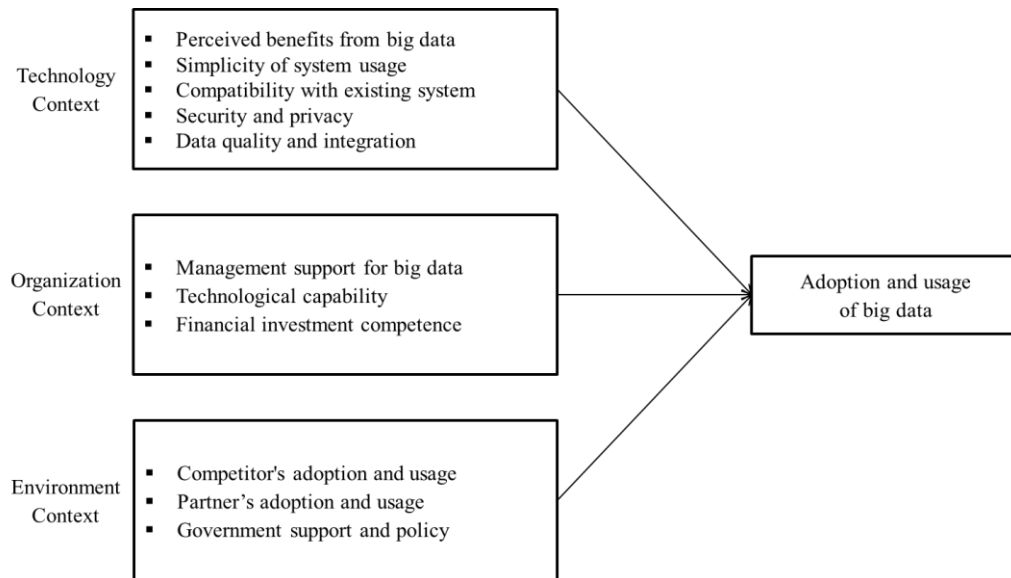
**Fig 1.** Research procedure

#### 3.1 Research model and the adoption factors

We established the research model using TOE conceptual model, as presented in Fig. 2.

Tomatzky et al. (1990) developed the Technology-Organization-Environment (TOE) framework to investigate the adoption and usage of technological products and services. The TOE framework investigates the

adoption factors from three contexts as follows: technological context including technology issues relevant to innovations, organizational context including internal resources and capabilities, and environmental context including competitors and industrial policy.



**Fig. 2.** Research model

We derived the influencing factors of big data with reflecting 5 expert opinions after regarding the survey results and the prior studies. Five experts have over 10 years of research experience in the interdisciplinary fields of IT technology and management at universities and government founded research institutes with at least a master's degree.

In technological context, we select perceived benefits from big data, simplicity of system usage, compatibility with existing system, security and privacy, and data quality and integration as the adoption factors for big data. Perceived benefits from big data are related to the degree to which firms perceive as receiving the benefits such as cost reduction, operation improvement and marketing performance from big data (Gartner, 2014). There is no reason to implement and utilize big data in firms without recognizing the benefits including usefulness or relative advantages. Therefore the perception of benefits form big data is main determinant of the adoption (Davis et al., 1989; Iacovou et al., 1995; Lin, 2014; Oliveira et al., 2014). Simplicity of system usage refers to the degree to which big data system is easy to implement and operate (NIA, 2014). Simplicity of system usage is related to the usability or availability of system. Therefore the simplicity in implementation and utilization would promote the adoption of big data in firms (Davis et al., 1989; Wang et al., 2010; Lian et al.,

2014; Gangwar et al., 2015). Compatibility with existing system is the degree to which big data is compatible current Information system (Accenture, 2014). Firms have been utilizing the information systems across the value chain and the data base management system such as customer relationship system (CRM) and enterprise resource planning (ERP). Therefore the system compatibility at the enterprise level would be task for the adoption of big data (Thong, 1999; Cao et al., 2014; Yang et al., 2015). Security and privacy are associated with the degree which to the obstacles of big data according to privacy invasions and security risks (Accenture, 2014; NIA, 2014). Security and privacy are likely to be barriers to the diffusion of big data (Cao et al., 2014; Kshetri, 2014; Lian et al., 2014). Data quality and integration refer to the degree to which the data analyzed from big data system is relevant to usage for big data applications and is integrated between the data collected (IBM, 2012; Gartner, 2014). The data collected from big data varies greatly in respect of type and quality depending on the sources of data. Therefore securing the quality of data and integrating the various data would be important task in the big data adoption (McAfee and Brynjolfsson, 2012; Kwon et al., 2014).

Management support for big data, technological capability, and financial investment competence are considered in organizational context. Management support refers to the degree to which management perceives the importance and relevance to tasks of big data (Gartner, 2014). The role of management in the information system acceptance and utilization are analyzed to be very large. Therefore management support is likely to promote the adoption of big data like other information system (Low et al., 2011; Cao et al., 2014; Lian et al., 2014). Technological adoption capability is related to the degree to which firms have the capability to operate big data system in terms of technological readiness (IBM, 2012; NIA, 2014). Technological adoption capability in firm is related to human resources, training and education, skill and experiences. The higher technological adoption capability is, the more likely to succeed in implementation and utilization of big data (Xu et al., 2004; Lian et al., 2014). Financial investment competence refers to the degree to which firms are able to invest in introducing and operating big data (Accenture, 2014; NIA, 2014). It takes a lot of financial investment to adopt big data in firms, including equipment, software package and consulting. The burden of financial costs is likely to cause firms to hesitate the big data adoption (Gibbs and Kraemer, 2004; Cao et al., 2014).

We regarded competitor's adoption and usage, partner's adoption and usage, and government support and policy in environmental context. Competitor's adoption and usage refer to the degree which to firms are influenced the decision-making of big data adoption according to the competitor's behavior. Partner's adoption and usage are related to the degree to which firms are affected big data adoption according to the behavior of the other firms in the partnership of marketing or product development. The competitor's and partner's pressure

effects like the advanced usage of competitor or partner were analyzed to be factors to facilitate the adoption of IT innovations as social influence. Therefore competitor's and partner's adoption and usage are likely to act as a determinant of the adoption of big data (Zhu et al., 2003; Lin and Lin, 2008; Low et al., 2011; Yang et al., 2015). Government support and policy refer to the degree to which firms are influenced the big data adoption according to government support and policy for activating the industry. The government policy and support related to open data, clouding computing and industrial promotion may stimulate the adoption of big data (Gibbs and Kraemer, 2004; Xu et al., 2004; NIPA, 2015).

### 3.2 Methodology

We conducted an expert survey for the data collection, and adopted the pairwise comparisons of the 9-point Likert scale on the survey items for AHP. We used AHP software and Excel for statistical analysis. AHP proposed by Saaty (1977) is wide used for identifying and prioritizing the critical factors of IT innovations adoption or market success (e.g., Adhiarna et al., 2013; Nikou and Mezei, 2013; Kim et al., 2014).

The experts had a master's degree or higher with at least ten years of experience in R&D, policy and business in IT sectors including more than three years in big data. 50 questionnaires were collected by a survey-specialized company through face-to-face interviews. Table 4 shows the experts' profile. Their main majors were in IT engineering (40.0%) and business administration (30.0%) and their average period of experience in IT is 16.4 years.

**Table 3.** Expert profile

Affiliation	Proportion	Detail
University	24.0%	Seoul National University, Hanyang University, Korea University, KAIST, POSTECH, Yonsei University, Konkuk University, Sungkyunkwan University, A-Joo university and etc.
IT research institute	36.0%	Korea Internet and Security Agency, Korea Science and Technology Policy Institute, Korea Information Society Development Institute, Electronic and Telecommunications Research Institute and etc.
Industry	40.0%	Samsung Electronics, LG, KT, SK telecom, Samsung SDS and LG Innovation, Technovation consulting, etc.

## 4. Results

Table 4 illustrates the weights of each context, and the local and global weights of each factor. The results meet the cut-off criteria of consistency ratio, less than or equal to 0.10 (Saaty, 1980).

Technology (0.455) is the most important among the three contexts, followed by organization (0.377) and environment (0.169). This result implies that there are many issues and challenges especially in the technological aspect because big data is in the stage of early technology development and initial market introduction. On the other hand, the relative importance of environment is not significantly high compared to technology and organization. This shows that the effects of technology and organization on the adoption of big data are stronger than that of environment.

Perceived benefits from big data (0.314) and data quality and integration (0.284) had the highest local weights, followed by security and privacy (0.210), compatibility with existing system (0.101) and simplicity of system usage (0.090) in technological context. This shows that benefit and attribute related to data are more important adoption of big data than others in technological aspect. Technological capability (0.367) had relatively high local weight, followed by financial investment competence (0.360) and management support for big data (0.272) in organizational context. This shows that technological and financial capabilities are important factors in organizational aspects. Government support and policy (0.378) had the highest local weight, followed by competitor's adoption and usage (0.376) and partner's adoption and usage (0.246) in environmental context. It shows that the competition relationship affects the adoption of big data in environmental aspect.

**Table 4.** AHP analysis results

Context	Weights	C.I	Factor	Local		C.I	Global	
				Weights	Ranks		Weights	Ranks
Technology	0.455	0.003	Perceived benefits from big data	0.314	1	0.020	0.143	1
			Simplicity of system usage	0.090	5		0.041	11
			Compatibility with existing system	0.101	4		0.046	9
			Security and privacy	0.210	3		0.096	6
			Data quality and integration	0.284	2		0.129	4
Organization	0.377		Management support for big data	0.272	3	0.003	0.103	5
			Technological capability	0.367	1		0.138	2
			Financial investment competence	0.360	2		0.136	3
Environment	0.169		Competitor's adoption and usage	0.376	2	0.004	0.064	8
			Partner's adoption and usage	0.246	3		0.042	10
			Government support and policy	0.378	1		0.064	7

※ C.I: Consistency Index  $\leq 0.1$

In global weight of each factor, perceived benefits from big data (0.143), technological capability (0.138), financial investment competence (0.136), data quality and integration (0.129), management support for big data (0.103) and security and privacy (0.096) were the top six factors influencing the adoption of big data in Korean firms. Whereas government support and policy (0.064), competitor's adoption and usage (0.064), compatibility with existing system (0.046), partner's adoption and usage (0.042) and simplicity of system usage (0.041) had relatively lower weights. This result reveals that benefit, attributes related to data and internal capabilities including technology and finance are critical factors in adopting big data in firms.

## **5. Conclusion**

### *5.1 Summaries and implications*

Big data is expected to drive new digital transformations to society, government and business by creating market opportunities, enhancing operational efficiencies, and reducing risks and costs. Big data is also likely to be positioned as the strategic necessities to bring competitive advantages across the value chain in firms. However there are many challenges and obstacles to diffuse big data in firms (Chang et al., 2014; NIA; 2014).

This study identified and prioritized the technology-organization-environment (TOE) factors influencing the adoption and usage of big data in Korean firms by using the AHP model. Hence, we summarized the results and proposed the implications in terms of businesses and policy for promoting the adoption of big data in firms.

First, Firm's perception of benefits from big data is the most critical determinant of big data adoption and usage. Big data is expected to provide much usefulness to enterprises including product bundling and pricing, channel management, service design, customer segmentation, and churn management (Chang et al., 2014). However, it is more important to have confidence in big data's tangible value such as revenue growth and cost reduction of firm. Therefore, to prevent failure of big data, it is necessary to dispel the lack of firm's perception on practical benefits through systematic risks management (IBM, 2012; Gartner, 2014).

Second, Technological capability is analyzed to greatly help the adoption and usage of big data in firm. To better take advantage of big data, firm should secure the related technology capability readiness in terms of the data management such as data collection, processing, and integrating, and the data analytics including data modeling, analysis, and interpretation (Gandomi and Haider, 2015). For this, it is required to recruit external experts, and foster internal experts by training and education on big data.

Third, since financial costs for implementing and operating are likely to act the obstacle, it is important to secure financial investment competence to facilitate the adoption and usage of big data in firms. Financial investment competence includes the efficient usage of budgets as well as the allocating investment funding. The matching between investment priorities and business strategy on big data would be a good solution to reduce investment budget (Biesdorf et al., 2013). It would be a good plan to increase return of investment (ROI) through developing the data-driven business models (Morabito, 2015).

Fourth, data concerns related to quality and integration, and security and privacy show relatively higher priorities among factors for adopting and utilizing big data in firms. Big data quality is closely related to the consistency and the completeness of data (Kwon et al., 2014). Data integration from various data sources including Internet, multimedia, social media and Internet of Things is very important elements for data utilization (LaValle et al., 2013). Data security and privacy invasion would act as inhibitors in implementing and activating big data in firms (Kshetri, 2014). Therefore the technological advance of data concerns should be done urgently by the ecosystem such as system vendors, or research and development institutes.

Fifth, management support for big data is expected to be the facilitator of big data adoption and usage in firms. Management support would directly help in the big data's diffusion inside the firms through investment decisions on big data system. Management interest and involvement such as matching organizational structure with big data, innovating organization culture, and decision-making based on big data would also promote the utilization of big data enterprise-wide (McAfee and Brynjolfsson, 2012).

Last, the factors related to government, competition, partner, and usage continence are relatively low priorities in firm's diffusion of big data. However these factors are likely to rise as critical issues for activating big data in firms. Government support and policy would especially act as the infrastructure. Government roles such as providing public data, fostering the experts, protecting intelligent property, and regulating for privacy and security would affect the diffusion of big data in firms (Kwon et al., 2015).

## *5.2 Limitations and further studies*

We conducted an almost initial investigation into the adoption and usage of big data in firms. However, there are the following limitations.

This study examined the big data's adoption and usage focused on firms. Big data is expected to also be utilized in health, finance, research and development, public sector and others. The determinants of big data

diffusion are likely to differ by size or by country as well as by industry. Hence, these comparative studies are the directions for further studies.

This study adopted the AHP method with the expert survey as research methodology. This methodology may be evaluated as useful in the initial stage of market introduction and system development, since the levels of the value perception by firms are very low. The empirical studies using data collected by the survey of firms are suggested as further studies.

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